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Implementation of a Multiyear Pre-Collegiate Engineering Research Program

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Implementation of a Multi-Year Pre-Collegiate Engineering Research Program (Evaluation)

Abstract

Baylor Research is a pre-collegiate research program that includes Engineering, Biomedical, and Environmental tracks. The mission of Baylor Research is to teach students to think like scientists and engineers through cutting-edge research projects taught by experts in those fields. This program was established in 2016 and is projected to support 68 research students within the curriculum in the 22-23 school year. Five science electives (Engineering Design, Molecular Methods, Research I, Advanced Research and Thesis Research) have been developed over the years to support breadth and depth in these topic areas. Research concepts and projects have also been implemented in core and Advanced Placement science courses. This work presents the infrastructure and methodology for successfully incorporating engineering topics such as computer vision, machine learning, virtual reality, and space systems into a high school classroom. Additionally, college preparedness and matriculation into STEM-related college fields is discussed.

Introduction

Improving science, technology, engineering, and mathematics (STEM) exposure and achievement in pre-collegiate settings has been a long time goal of the education field at a local, regional, and national level [1], [2]. It has been found that increased, consistent exposure to STEM topics and skills in a pre-collegiate setting facilitates post-secondary study and/or workforce development [1]. While an abundance of literature has repeatedly demonstrated that project-based learning / experiential learning effectively improves student engagement and understanding [3]–[5], sporadic and short-term activities are less effective [6].

In the past decade, there has been an increasing number of collegiate-level research experiences tailored to secondary students. In fact, the Common Core State Standards for Mathematics encourage high school student engagement in authentic research [7], [8], and the College Board introduced an AP Research course offering in 2014 [9]. Other models that incorporate research in a high school setting have also emerged. Many such programs have similar underlying findings: engagement in real-world research taught/led by professional scientists/engineers improve science and math comprehension. Other skills such as reading comprehension, and writing were also shown to be significantly improved [10]–[13]. As performing scientific and/or engineering research addresses the top three levels of Bloom's Taxonomy: Analyze, Evaluate, and Create [14], it is clear that continuing to foster models that incorporate these skills in a pre-collegiate setting should be highly encouraged.

The work presented here outlines an in-school model that promotes problem solving and critical thinking through real-world research taught by experts in the field. Specifically, the infrastructure and efficacy of the Engineering Research portion is detailed. Concepts, course descriptions, and assessment tools presented here were designed to be modular so that other institutes interested in integrating research into secondary school curriculum could adapt these components to fit individual constraints.

Methods

Program Overview
Baylor Research (BR) is a pre-collegiate research program that includes Engineering, Biomedical, and Environmental topics. The program resides within the Science Department with four faculty (the principal scientist in Environmental Research, the principal scientist in Biomedical Research, and two principal engineers in Engineering Research) who hold higher degrees in their respective field. The mission of Baylor Research is to teach students to think like scientists and engineers through cutting-edge research projects. This program was established in 2016 and currently (2022-23) supports 68 research students within the curriculum. Five science electives (*Engineering Design*, *Molecular Methods*, *Research I*, *Advanced Research* and *Thesis Research*) have been developed over the years to support breadth and depth in these topic areas.

Entry into the program can occur as early as 10th grade year. Students entering the BR Program must have successful completion or concurrent enrollment in Chemistry and earn a minimum of a B; this requirement is based on the ability of the student to have a strong understanding of mathematical concepts and the application of mathematical concepts toward a discipline of science; chemistry seems to be a strong indicator of student performance in this area. The progression through the program is outlined in Figure 1. Year One includes either *Molecular Methods* (for Biomedical and Environmental Research tracks) or *Engineering Design* (first semester); students can self-select their preferred discipline at this point. If students decide to continue in the program, the following semester includes *Research I: Engineering*, *Research I: Biomedical*, *Research I: Environmental*. For students that started earlier than their 12th grade year and have scored above 85 in *Research I*, they are eligible to continue to *Advanced Research*, which is a year-long elective. And finally, those students who complete *Advanced Research* with an 85 or above have the option to progress to *Thesis Research* in their respective discipline.

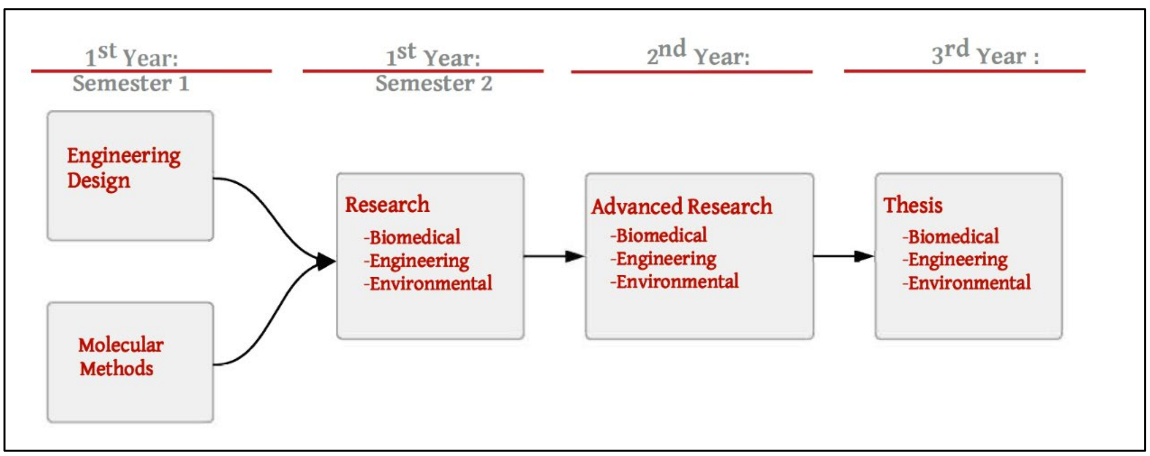

Figure 1. BR Course Progression

Three lab spaces have been designated on the first floor of the science building. Table 1 lists the primary equipment available for the research students.

Table 1. Lab Equipment List

Engineering Lab	Biomedical and Environmental Lab Equipment
BK Precision 9129B DC Power Supply	KingFisher™ Duo Prime Purification System
BK Precision 4003A 4MHz Function Generator	FLUOstar OPTIMA Microplate Reader
Tektronix TBS1064 60 MHz Four Channel Digital Storage Oscilliscope	ChemiDoc Imaging System
Saleae Logic Analyzers	Chai qPCR Thermocycler
TM 1000 Scanning Electron Microscope	QuantStudio 3 Real-Time PCR System
3D Printers (Makerbot, Ultimaker, and Form 2)	MiniAmp Thermal Cycler
Shapeoko 3 CNC Router	Countess™ II FL Automated Cell Counter
Epilog Helix 40W Laser Cutter	Purair BIO Biological Safety Cabinet
Two ASUS Core i7 Performance Gaming Desktop with GeForce GTX 1080	Leica DMIL LED Inverted Fluorescence Microscope
2 Oculus Rift Systems	Leica DM2000 LED Fluorescence Microscope
3 Oculus Quest 2 VR Headsets	Laminar Flow Hood
	CO2 Jacketed Incubator
	-80 degree Freezer

The BR program is financially supported by an endowment gifted by the family of a school alumnus. The endowment provided the construction of the science building, perpetual maintenance on the science building, as well as a generous budget for the science department and other STEM-related endeavors.

Research Scholars Designation

With the support of the administration, Research Scholar designation can be given to students that complete (at minimum) *Advanced Research* courses as well as four high-level (Honors/AP) science and mathematics electives (*e.g.*, *AP Physics*, *AP Computer Science*, and *Abstract Mathematics*). This designation is applied at graduation and distinguishes students who have gone beyond curricular requirements in areas of STEM.

Engineering Research

<u>Engineering Design Course (1 semester)</u>

The Engineering Research discipline begins with *Engineering Design*, which is a semester-long elective that introduces the various ways engineers/scientists take an idea and produce an output using the Engineering Design Cycle. Students engage in lessons, tutorials, and projects to learn skills including programming, electromechanical systems, and modeling that are ubiquitous in many engineering disciplines. Skills in this course map well to Next Generation Science Standard (NGSS) HS-ETS1-1 and HS-ETS1-2.

Engineering Design is a hybrid flipped-classroom model. Toward the beginning of this semester, this course focuses on skill-building by undergoing a series of mini design challenges as shown in Figure 2. To prepare for each design challenge, learning the tool or skill is an amalgam of online video tutorials (outside-of-class preparation) and practical tutorials (in-class practice). Then, students work on a mini design challenge based around the skill upon which they are focusing. Each challenge has components that are assessed. The outside-of-class preparation typically involves watching a video and taking an online "checkpoint" assessment to ensure understanding of the material that will be practiced in class.

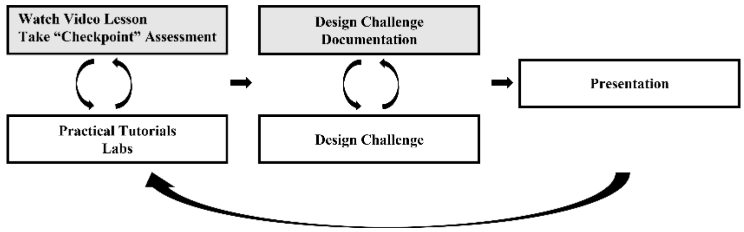

Figure 2. Using the flipped classroom model, each skill (programming, electromechanical systems, and modeling) iterates through watching video lessons (out-of-class as marked by gray) while working on in-class practical tutorials. Once sufficiently trained, a design challenge is introduced, which includes an out-of-class documentation component. The project culminated with the presentation to peers.

Toward the end of the semester, papers and presentations that illustrate the type of research involved in the Engineering Lab are presented. During these times, students are also taught how to read a scientific/technical paper. Like the flipped classroom model previously discussed, students read sections of a class-wide paper as homework and discuss/analyze it in class the following day (NGSS RST.11-12.7, RST.11-12.8, and RST.11-12.9). .

The final exam for the course involves submitting a project proposal. Based on the presentations of current research areas in this lab and the skills gained throughout the semester, students select a problem/question and, working through the design cycle, write a technical proposal as to how you would solve this problem/answer this question. This is the culmination of the course and reflects the student's ability to describe a problem and design a potential solution regarding something that they feel passionately about while referencing tools they have learned along the way (NGSS HS-ETS1-1, HS-ETS1-2, RST.11-12.7, RST.11-12.8, and RST.11-12.9). These projects typically lead to *Research I: Engineering* topics.

Research I: Engineering Course (1 semester)

Students completing *Engineering Design* with a grade of 85 or higher are eligible to work on individual projects in *Research I: Engineering*. Engineering students are granted the freedom to pursue their independent research projects. Most student research are supported by existing BR projects. However, student proposals not related to existing projects are considered, but approval depends on feasibility and cost. The goal of *Research I: Engineering* is twofold: 1) to hone research techniques started in *Engineering Design* (scientific literature, problem solving, time management, *etc…*) and 2) to ramp up research project (learn more about the topic, begin initial experiments, *etc…*).

As students entering *Research I: Engineering* may be at different phases of the project, phases of learning material, and previous exposure to specific learning material, goals and progress are assessed individually through a series of assessments shown in Figure 3.

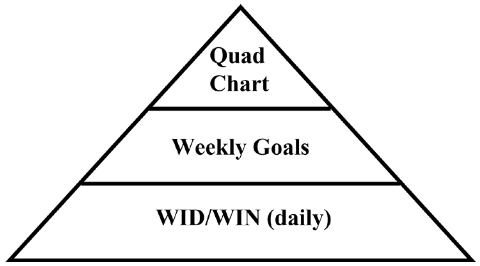

Figure 3. Assessments for *Research I: Engineering* that target time and project management. Each level decreases in frequency (daily, weekly, monthly) but increases in weighting.

A “WID/WIN” stands for “What I Did / What I Need” and is a daily reflection that answers four questions: 1) What did I do today? 2) What will I do tonight to progress my project? 3) What do I need from my faculty adviser? and 4) How do I feel today? This is a low stakes assessment and was designed to provide a common place for students to convey if they are stuck on their project and to remind them to give themselves homework. Each week or class rotation equivalent students submit actionable and detailed goals to accomplish (Weekly Goals). This moderately weighted assignment allows them to grow in time management while developing ambitious and yet achievable action items. This is a retrospective grade such that the faculty instructor and student discuss if the previous goals were met and why/why not. (NGSS HS-ETS1-1 and HS-ETS1-2) Approximately each month, the students present a five-minute presentation that illustrates progress and expectation for the next month; this presentation is one slide, broken into four parts (Quad Chart) as shown in Figure 4.

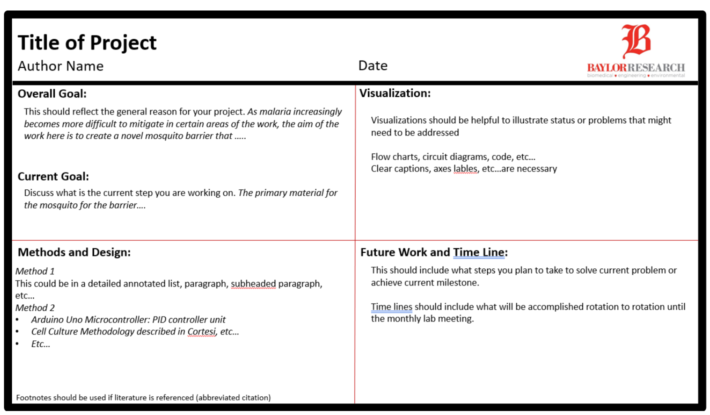

Figure 4. The template for the 5-minute Quad Chart presentation, given approximately every month.

Briefly, overall and current goals are presented in the first section, followed by the current methods they are employing on their project. The visualization must be made by the student; this encourages students to make diagrams/figures/annotated images for future publications (if applicable) in addition to translating project understanding. And finally, a longer timeline is proposed/presented. The presentation of this updated work encourages public speaking and answering peer questions help eliminate holes in the work and foster understanding [15].

The final three assessment categories include building a technical paper (section by section). For example, the student submits a draft of the Introduction section; during the next submission, they submit revisions of the Introduction and a draft of the Methods. Each iteration is weighted more as they are further in the process of developing these writing skills. At the end of the year, students are required to present a poster, which they created, at the Science and Engineering Symposium at the end of the academic year (NGSS RST.11-12.7, RST.11-12.8, and RST.11-12.9).

Advanced Research: Engineering and Thesis Research: Engineering Courses (1 year / each)

Upper-level Research courses share several assessments (WID/WIN, Weekly Goals, Quad Charts, Paper Submissions, and Poster Presentation) with some additional assessments. During *Advanced Research* and *Thesis Research*, students are given a Content Assessment, a multi-day/week, open book/note assessment to ensure foundational learning about the project application. This assessment parallels a preliminary examination in graduate school. *Advanced Research* students are also required to submit to an external competition, journal, or conference in addition to presenting at the yearly symposium (NGSS HS-ETS1-1, HS-ETS1-2, RST.11-12.7, RST.11-12.8, and RST.11-12.9).

Building on the *apriori* expectations of *Advanced Research*, *Thesis Research* students must select a committee member that will review their final thesis document. This committee member is often science faculty that teaches core curriculum closest to the thesis student's research topic. Students must answer questions about their research as well as craft an outreach presentation that translates their research topic into the committee member's foundational science or math class (NGSS HS-ETS1-3, HS-ETS1-4, MP-2, and MP-4). This presentation is then given during the final semester in the applicable science course.

Statistical Analyses

Programmatic growth throughout each year (and within each discipline) with respect to the number of students were collected. A pre- ($N = 140$) and post-survey ($N = 99$) was conducted during six years of *Engineering Design*. Each survey was voluntary and anonymous. Pre-surveys were administered within the first week of *Engineering Design* class. This survey served two purposes: to identify any incorrect pre-conceived notions about engineering and to determine areas of interest for the students. Other questions that indicated how the students perceived their strengths of certain skills were included. These questions were scored based on a Likert scale, where 5 is a high ability in that area and 1 is a low ability in that area. Post-survey data was collected during the last week of school. Questions included in these analyses were the same question/topic. Participation in the survey was approximately 78% (from approximately 180 enrolled students in 6 years) for the pre-survey and 55% for the post-survey. Data were quantitatively compared using a standard t-test (two-tailed, assuming heterogeneous variance).

Results

Program Growth

Since implementing research-based curricular and extracurricular components in 2015-16, Baylor Research has shown exceptional growth in all discipline areas as shown in Figure 5.

Each year demonstrates growth except for 2020-21, as denoted by the '*'. During this time, the Covid-19 pandemic impeded recruitment and enrollment into the research areas. However, in subsequent years, even under changing research faculty in two disciplines, the numbers not only recovered but continued to grow.

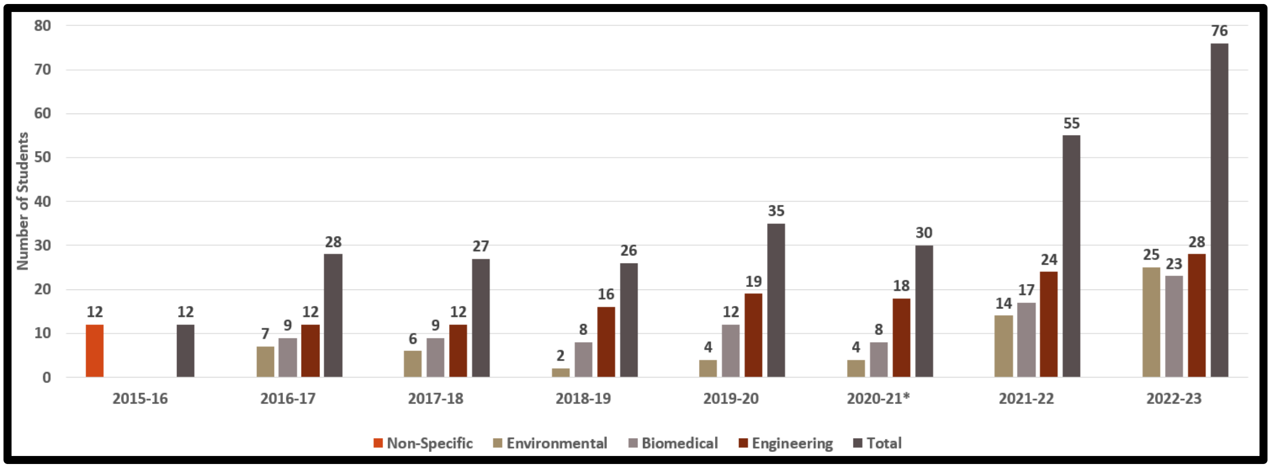

Figure 5. The number of students enrolled in research throughout each year of program. Engineering Research, indicated in deep red follows the trend of the overall programmatic growth as well.

An additional Engineering faculty member was added in 2022-23 allowing the number of students that could be supported by the Engineering discipline to increase.

Class Surveys

Table 2 and Figure 6 show the average, standard deviation, and resulting p-values from the t-test.

Table 2. Results of the Pre- and Post-Survey Questions in *Engineering Design*

Question	Pre-Survey Average	Pre-Survey Std Dev	Post-Survey Average	Post-Survey Std Dev	P-Value
Ability to use engineering principles to analyze a problem/process.	3.23	1.08	4.03	0.83	0.000
Ability to design solutions to meet desired needs.	3.73	0.87	4.12	0.58	0.015
Ability to work in teams.	4.28	0.88	4.26	0.82	0.925
Ability to communicate effectively with team members.	4.31	0.87	4.32	0.72	0.931
Ability to effectively resolve conflict.	4.10	0.86	4.03	0.71	0.656
Ability to use feedback from an experiment to improve solutions to problem.	4.25	0.74	4.24	0.77	0.909
Ability to navigate a technical/scientific paper.	3.19	0.95	3.79	0.99	0.000
Ability to convey technical ideas in writing.	3.22	1.05	3.59	0.88	0.065
Ability to convey technical ideas verbally.	3.56	0.95	3.88	0.80	0.073
Knowledge of engineering-related skills.	2.68	1.08	4.08	0.86	0.000
Ability to present in front of colleagues/peers.	3.61	1.08	4.03	0.92	0.040

Significant ($p<0.01$) increases were noted in the ability to use engineering principles to analyze a problem, navigate a technical paper, and knowledge of engineering-related skills. Improvements ($p<0.05$) were observed in the ability to design solutions to meet desired needs and present in front of colleagues/peers. Of note, the ability to convey technical ideas in writing ($p=0.065$) and verbally ($p=0.73$) were also trending upward.

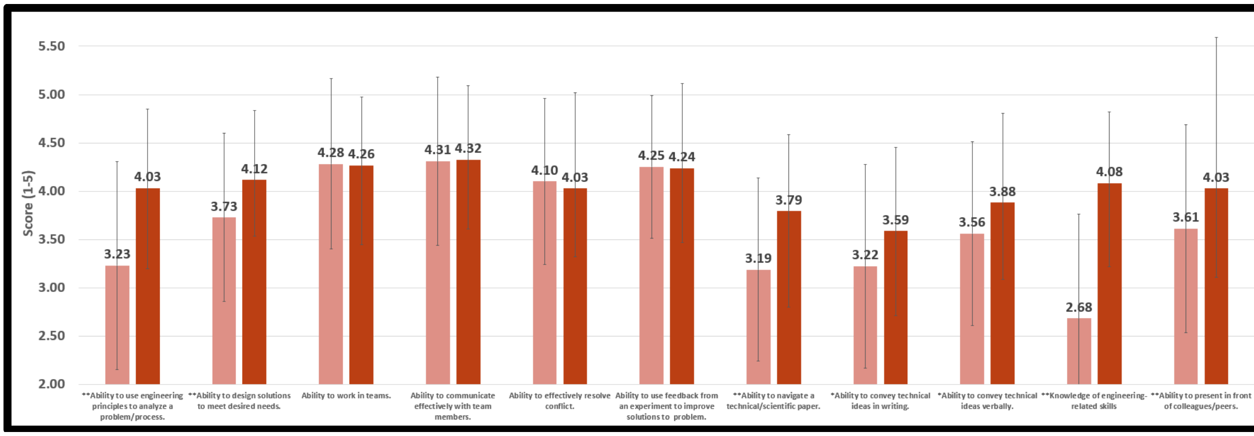

Figure 6. Results of the Pre (pink)- and Post (red)-Survey Questions in *Engineering Design*. Significance is indicated by column label **($p<0.01$) and *($p<0.05$)

End-of-the-semester surveys were also conducted in *Research I, Advanced Research*, and *Thesis* classes. Figure 7 shows the results of three of the most pertinent categories (N = 38). Students overwhelmingly feel that they can navigate scientific literature as well as solve problems much more confidently after time spent in the research program.

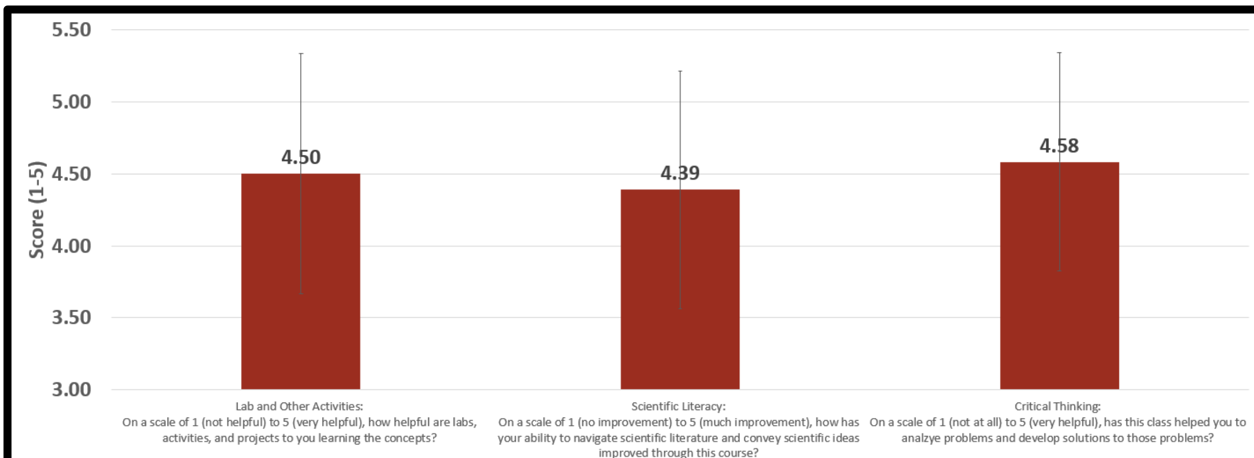

Figure 7. Results of Post-Survey (N=38) from *Research I*, *Advanced Research*, and *Thesis*. Error bars indicate standard deviation.

Work Quality Outputs

Students in *Research I*, *Advanced Research*, and *Thesis Research* are required to present a poster at the annual school-wide Science and Engineering Symposium at the end of the academic year. Additionally, *Advanced Research* and *Thesis Research* students are required to submit work to

external outputs (local, regional, or national level). Table A1 (see **Appendix**) lists details of the external outputs from 2016-2022 from Engineering Research students to provide scope. The Chattanooga Regional Science and Engineering Fair (CRSEF) is a qualifier for the International Science and Engineering Fair (ISEF), and students are encouraged to submit their work each year.
To summarize, between 2016-2022, nine unique student projects were presented and published at regional/national conferences. Students have also presented projects and findings at colleges such as the University of Tennessee at Chattanooga, Tennessee Technological University, and the Massachusetts Institute of Technology. Students have received numerous awards for their work, such as the Grand Prize for the national NASA OPSPARC Challenge (2016-17), over 10 awards at CRSEF, as well as the High School Division award at the University of Tennessee at Chattanooga Technology Symposium. Outputs have ranged from oral presentations, poster presentations, and written proceedings/papers. Citations have been included where relevant in Table A1.

Also detailed in the table is the Title or Citation to indicate breadth and depth of engineering-related topics. These content areas were offered by the faculty mentor's ability to provide both academic and financial support for the project. Collaborations with local universities/partners are also evident. While BR can support research projects in house, collaborations for clinical trials (*e.g.,* the virtual reality calm/sensory room) were instrumental to test new technologies in meaningful and ethical way.

Discussion and Future Work

Baylor Research consists of three modules designed to train students in all facets of scientific research. Starting in *Engineering Design*, allowing students to engage in project-based skill building in a hybrid flipped classroom has shown a perceived growth in several key areas (Table 2): 1) the ability to use engineering principles to analyze a problem, 2) the ability to navigate a technical paper, 3) knowledge of engineering-related skills, 4) the ability to design solutions to meet desired needs and 5) the ability to present in front of colleagues/peers. The ability to convey technical ideas in writing and verbally also showed perceived improvement and were close to significance.

The confidence in these key areas allowed a subset of students to enter future Research classes. While the post-survey questions differed from those asked in *Engineering Design* and pre-survey questions were not offered, the scores shown in the post-survey data (Figure 7) suggest that student maintain this perceived ability to solve problems, think critically, and navigate scientific literature.

These findings were important in that students in these courses were given the opportunity to engage in very advanced engineering material. By examining Table 3, the titles of the project indicate the breadth and depth of these content areas. In Engineering, topics ranged from virtual reality (VR) development for healthcare applications, cube satellite technology, networked mobile robotics, and computer vision. Within the study and execution of these projects, students honed skills in time management and appropriate goal tracking (WID/WIN, Weekly Goals, and Quad Charts) as well as communication of highly technical work (Science and Engineering

Symposium and external outputs listed in Table 3). The fact that students maintain a high level of perceived confidence in critical thinking, problem solving, and navigating scientific literature echoes the success of this infrastructure to introduce these advanced topics pre-collegiately.

While student matriculation was not tracked, there has been anecdotal evidence that suggests student confidence continues in STEM-related classes in college. Students have conveyed (verbal and written) confirmation of similarities between Engineering Design (high school) and Introduction to Engineering courses at colleges. Additionally, students also shared gratitude for being introduced to standard engineering-related platforms/software (*e.g.,* AutoDesk, Matlab, Python, ROS, etc…) prior to college. While there is no quantitative evidence, having additional knowledge and/or confidence in STEM material during such an important social transition year for students seems to have benefitted students in the BR research program.

The program presented here demonstrates the development of an *in-situ* high school research program. The course progression, course elements and assessments, and topics studied, specifically in Engineering, allow for high school students to engage in collegiate-level research as well as develop skills and confidence in areas of problem solving, critical thinking, and communication. The elevated level of work has garnered recognition from a number of local-, regional- and national-level external competitions/conferences. Future work would include working with Admission and Development Offices on campus in order to understand motivation for students joining this ever-growing program as well as following up with Alumni regarding subsequent college-preparedness and career trajectories.

Acknowledgements

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Appendix

Table A1. External Output of Student Work

2021-22	Output Type	Title or Citation	Submission Details
	Poster Presentation, National Conference	Haley Harwood and Mary Loveless; *Effectiveness of Virtual Reality Calm Room Interventions on Student Behaviors*. Am J Occup Ther July 2022, Vol. 76(Supplement_1), 7610510187p1.	The American Occupational Therapy Association National Conference. July, 2022
	Presentation, Science Fair	*Production of a Spherical Air Bearing for Testing an Attitude Control System for a Cube Satellite*	CRSEF 2022: Engineering Mechanics, 1st place
	Presentation, Science Fair	*A Study Toward Improving Cube Satellite Payloads and Ground Testing*	CRSEF 2022: Embedded Systems, 1st place
	Presentation, Science Fair	*Virtual Reality Interactive Therapy For Autism Spectrum Disorder (ASD)*	CRSEF 2022: Systems Software, 1st place
	Presentation, Science Fair	*Low-Level Communication and Control for an ORB-SLAM Robotic System*	CRSEF 2022: Robotics and Intelligent Machines, 1st place
2020-21			
	Virtual Presentation	*Variable Geometry Suspension with Active Toe Control*	University of Tennessee at Chattanooga Technology Symposium, April 2021
	Virtual Presentation	*Attitude Control of Cube Satellites*	University of Tennessee at Chattanooga Technology Symposium, April 2021
	Virtual Presentation	*Water Filtration Via Graphene Membranes*	University of Tennessee at Chattanooga Technology Symposium, April 2021
	Virtual Presentation	*3D Printing Microfluidic Devices*	University of Tennessee at Chattanooga Technology Symposium, April 2021
	Virtual Presentation	*Concussion Therapy with Virtual Reality*	High School Award, University of Tennessee at Chattanooga Technology Symposium, April 2021
	Virtual Presentation	*Active Virtual Reality Sensory Room*	University of Tennessee at Chattanooga Technology Symposium, April 2021
	Presentation, National Conference	*Feasibility of Virtual Reality Calm Room Technology as a Sensory Regulation Modality in Schools*	5th Annual Virtual Reality and Healthcare Global Symposium, March 2021 (collaborator presentation)
2019-20			
	Presentation, Regional Conference	*Characterizing XBee S2Cs in a DigiMesh Topology for WSN Applications*	2020 IEEE SoutheastCon, April 2020 (Virtual)
	Proceedings, Regional Conference	Connor Duffy, Benjamin Sparkman and Mary Loveless, *Characterizing XBee S2Cs in a DigiMesh Topology for WSN*	

		Applications. 2020 SoutheastCon, Raleigh, NC, USA, 2020, pp. 1-6.	
	Presentation, Science Fair	*Tube Climbing Robot with Active Adjustable Diameter*	CRSEF 2020: Robotics and Intelligent Systems Division, 1st place
	Presentation, Science Fair	*Fabrication of Microfluidic Devices Using Stereolithographic 3D Printing*	CRSEF 2020: Biomedical Engineering Division, 2nd place
	Presentation, Science Fair	*Feasibility Study of Concussion Rehabilitation using Virtual Reality (VR)*	CRSEF 2020: Biomedical Engineering Division, 1st place
	Proceedings and Presentation, National Conference	Vincent Betro and Mary Loveless. *Creating a Relevant, Application-Based Curriculum for High Performance Computing in High School*. Volume 11, Issue 1, pp. 81 – 87	Faculty Submission, Super Computing Conference, Denver, CO, November 2019
2018-19			
	Proceedings, National Conference	Atherton Mook and Mary Loveless. *Virtual Reality Based Environment for Immersive, Hands-On Learning*. PEARC '19: Proceedings of the Practice and Experience in Advanced Research Computing on Rise of the Machines (learning). July 2019 Article No.: 92 Pages 1–4.	
	Poster, National Conference	*Virtual Reality Based Environment for Immersive, Hands-On Learning*	Practice and Experience in Advanced Research Computing, July 2019
	Proceedings, National Conference	Jade Liu and Mary Loveless. *A Virtual Reality Approach to Pediatric Conflict De-escalation and Anger Management.* PEARC '19: Proceedings of the Practice and Experience in Advanced Research Computing on Rise of the Machines (learning). July 2019 Article No.: 91 Pages 1–5.	
	Poster, National Conference	*A Virtual Reality Approach to Pediatric Conflict De-escalation and Anger Management*	Practice and Experience in Advanced Research Computing, July 2019
	Poster, National Conference	*Small Unmanned Aerial Vehicles to Combat Malaria*	American Society for Tropical Medicine and Hygiene, October 2018 (student contributed)
2017-18			
	Poster, National Conference	*Virtual Reality Calm Room*	The American Occupational Therapy Association National Conference. April 20, 2018
	Presentation, Science Fair	*Forest Fire Detection System*	CRSEF 2018: NASA Earth System Science Award
	Presentation, Science Fair	*Networked Reconnaissance Rovers for Disaster Environments*	CRSEF 2018: Robotics and Intelligent Systems Division, 1st place

	Local and International Science Fair Presentation	*Virtual Reality Calm Room*	CRSEF 2018: Intel Excellence in Computer Science, Software Systems division, 1st place, and Intel ISEF “runner up”
2016-17			
	Student Presentation	*Using Virtual Reality to Demonstrate Evolutionary Transitions in Biology*	Tennessee Technological University iCube facility, Cookeville, TN April, 2017
	Student Presentation	*Creating a Virtual Reality Curriculum Component for the Solar System*	Tennessee Technological University iCube facility, Cookeville, TN, April, 2017
	National Competition	*Microshutter Array Fiber Optics*	NASA Optimus Prime Spinoff Promotion & Research Challenge (OPSPARC), grand prize
	Student Presentation	*Rendy’s Diner: A Virtual Reality Experience for Assisted-Living*	The Martin Trust Center for MIT Entrepreneurship to Rendever, Boston, MA, February 2017